CFD Modeling of Urea-Based SNCR and Hybrid Performance on Large Utility Boilers

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Nalco Fuel Tech has conducted studies for the commercial application of its post combustion NOx reduction products to four large, coal fired, utility electric power boilers. The cases studied were a F-W 620 MWe opposed wall fired unit, a 750 Mwe C-E T-fired unit with LNCFS III, a 620 Mwe B&W unit with two-burner cells, and the same cell-fired unit with conversion to low NOx burners. Options were identified for applying NFT's NOxOUT® and NOxOUT CASCADE® systems. The analysis provided the basis on which commercial performance guarantees were offered. Various levels of reduction were identified, which can be applied in successive steps.

NFT's commercial design methods, comprising computational fluid dynamics (CFD), chemical kinetics (CKM), and injection simulation modeling, provided the analytical basis for estimating performance. Field measurements were made to obtain data for validating the CFD models. Temperature profiles in each unit were mapped with multiple high velocity thermocouple (MHVT) equipment.

The evaluations were performed for the generating companies operating these units. They were contracted to assess options for meeting the NOx reductions required in the Ozone Transport Region and the "fine grid" region affected by EPA's recently proposed SIP call for regional NOx reductions. Nalco Fuel Tech has extended commercial performance guarantees as follow-up to the studies.

NOxOUT® is the technology for applying urea based selective non-catalytic reduction (SNCR) for NOx reduction. Nalco Fuel Tech has commercially applied this product to more than 200 units world-wide ranging from small fire-tube package boilers to utility electric steam generators producing 320 MWe. NOxOUT® is currently operating in 12 commercial applications larger than 100 MWe. The design methods used for these studies are the tools that are routinely used for commercial design.

NOxOUT CASCADE® is a hybrid of urea SNCR with SCR. The source of the ammonia for the SCR can be the slip from an upstream SNCR process, thereby relieving constraints on ammonia slip. With the SNCR/SCR hybrid, the SNCR portion can be extended to regions of lower temperatures where chemical utilization is high. Increased NOx reduction at higher chemical utilization is achieved. Since a substantial portion of the reduction occurs with SNCR, the catalyst can be a small part of what would be required for a full SCR system. In some cases the SCR section is "in-duct" and designed merely to remove the NH_3 slip constraints on the SNCR. In other cases a larger catalyst is practical. Then, additional reductant feed can be generated to further increase the overall NOx reduction. NOxOUT CASCADE® is currently at the "first commercial use" stage of development.

Both SNCR and SNCR/SCR hybrid are aimed at providing cost effective NOx reduction with low capital investment. They enable beneficial trade-off of operating cost, capital costs, and impact of installation. Installation can be in steps, with urea SNCR first, then SCR hybrid later. In cases where space for retrofitting is limited, the small catalyst of the hybrid system can often be accommodated where a full SCR system cannot.

A total of 10 CFD models were run. Three load conditions were modeled for each of the three units. The cell-fired unit was modeled at full load with combustion conditions simulating the delayed combustion processes of low NOx firing. For comparison a case at full load was examined simulating existing burner performance. Time-temperature data from the CFD output, along with species data for baseline NOx and CO conditions, provided input into NFT's Chemical Kinetics Model (CKM) for the study cases. The kinetics data were used to identify the maximum and minimum temperature targets for injection and the potential for achieving a final NOx level of performance at acceptable ammonia slip values. The constraint on ammonia slip was relaxed when extending the process for SNCR/SCR hybrid. Injection arrangements were simulated in order to identify achievable performance. The maximum and minimum temperature targets for each case were applied to the CFD models to define the target region for injection. The injection model was utilized to compute and visualize chemical release patterns.

The expected performance results for the full load cases are summarized in the following table:

Unit/Option	T-Fired LNCFS III	Opposed Wall-Fired	Cell-Fired Before Mod.	Cell-Fired Low-NOx
Baseline (lb/10^6Btu)	0.43	0.65	1.10	0.57
Urea SNCR Wall Injectors	0.32	0.49	0.80	0.48
[NSR]	1.0	0.8	1.1	0.8
Urea SNCR MNL	0.28	0.40	0.65	0.40
[NSR]	1.2	1.4	1.2	0.8
Urea SNCR Increased Slip	0.26	0.33	0.50	0.35
[NSR]	1.1	1.4	1.4	1.1
Urea SNCR/SCR Hybrid	0.23	0.27	0.45	0.30
[NSR]	1.1	1.4	1.4	1.1
Overall NOx Reduction	47%	58%	60%	47%

The overall NOx reduction above is based upon using a small amount of catalyst in the back-end of the boiler. The reductant for this would be generated from the SNCR process, essentially at a slightly increased slip level. Substantially greater reductions can be achieved in cases where a larger SCR section could be easily installed. Then, urea would be injected in the back-end of the boiler to generate reagent feed to the SCR.

The highest percent reduction would be achieved on the cell-fired unit if treated before modification to low NOx burners. However, the lowest emissions level is possible on the T-fired boiler. Simplistically, the first parts removed are easier than the last. And, even though the T-fired unit is hot and difficult to treat, the low baseline allows reduction to an even lower emissions value.

Reductions can be obtained in stages. Wall injectors are fairly simple and inexpensive to install. Water cooled multiple nozzles lances (MNLs) enable injection in the cooler convective sections. MNLs add complexity and cost, but enable substantially increased performance. Relaxing the limits on ammonia slip by adding a catalyst downstream results in improved chemical utilization in the SNCR section. Pushing the slip to feed a downstream catalyst further reduces NOx without increasing chemical consumption.